

On the Top Mass Reconstruction Using Leptons

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Abstract. I discuss the feasibility of measuring the top quark mass by the using of final states with leptons and J/ψ at hadron colliders. I also investigate the impact of matrix-element corrections to the HERWIG simulation of top decays.

Top quark physics is presently one of the most interesting fields of investigation in both theoretical and experimental analyses. In the next Tevatron RUN II and, ultimately, at the LHC, a large amount of $t\bar{t}$ pairs will be produced, which will allow precision measurements of the top quark properties and especially of its mass.

In $t\bar{t}$ events at hadron colliders, the final states are classified according to the decay modes of the two W bosons produced in the decays $t \rightarrow bW$. At the Tevatron RUN I, the top mass was determined by means of the lepton + jets and the dilepton modes by both CDF and DØ collaborations, CDF also considering the all-hadron mode. The estimated average value for the top mass reads [1]: $m_t = 173.8 \pm 3.5 \pm 3.9$ GeV.

In this talk I discuss the method of reconstructing the top mass by means of final states where the two produced W bosons decay leptonically, i.e. $W \rightarrow l\nu$, l being either an electron or a muon, and the B meson, coming from the hadronization of the b quark, decays into a state containing a J/ψ , eventually decaying into a $\mu^+\mu^-$ pair. According to the LHC experimentalists [2], this is a favourite channel, with the estimated systematic error being no larger than 1 GeV. In three years of high luminosity $L = 3 \times 10^5$ pb⁻¹, about 3×10^3 final states with well-identified leptons and J/ψ s are foreseen. The idea is that one should relate the peak value of the distribution of the invariant masses $m_{J/\psi l}$ and $m_{\mu l}$ to the top mass by the using of Monte Carlo simulations.

The suggested channel presents some advantages which make it quite suitable: the backgrounds are small and can be suppressed by setting cuts on the transverse momentum and rapidity of the final-state leptons; the effects of the initial- and final-state radiation are negligible and can be easily taken into account; the spectra $W \rightarrow l\nu$ and $B \rightarrow J/\psi$ are well known.

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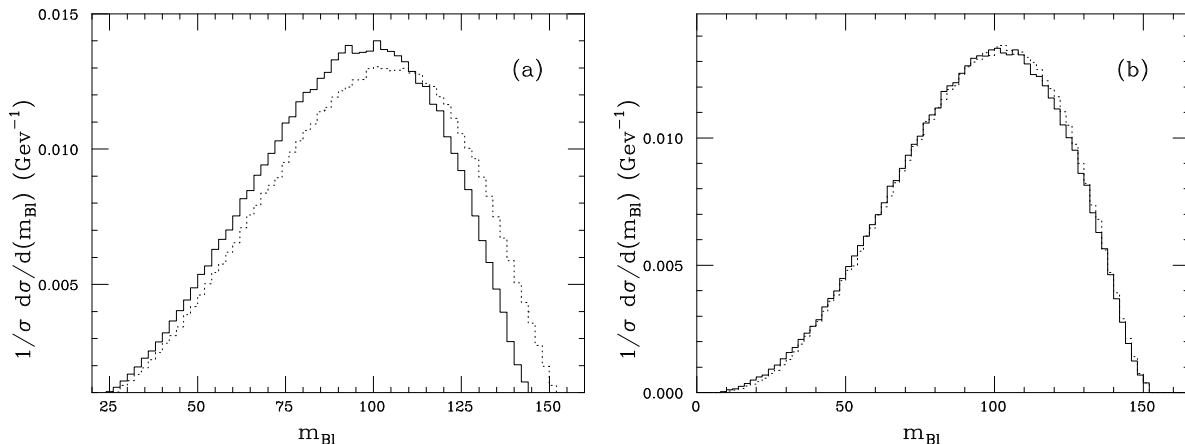


Figure 1. Invariant mass of the B -lepton system at the LHC for $m_t = 171$ GeV (solid) and $m_t = 179$ GeV (dotted), according to HERWIG 6.1 (a); for $m_t = 175$ GeV, according to HERWIG 6.0 (dotted) and 6.1 (solid) (b).

Since the proposed method crucially relies on the Monte Carlo model used to simulate top production and decay, I wish to investigate the effect of matrix-element corrections to top decays recently implemented [3] in the HERWIG algorithm [4]. As the $B \rightarrow J/\psi$ spectrum is well known, I shall consider the spectra of m_{Bl} . In HERWIG 5.9, the latest public version, a few bugs were found in the implementation of top decays. These bugs are corrected in the intermediate version 6.0, HERWIG 6.1 being the new version, including also matrix-element corrections to top decays. The Tevatron statistics will be too low to detect J/ψ s via top quarks. It is however worthwhile performing the analysis even at the Tevatron to check the consistency of the method which claims to estimate the top mass independently of the production mechanism, which is mainly $q\bar{q} \rightarrow t\bar{t}$ at the Tevatron and $gg \rightarrow t\bar{t}$ at the LHC. In Fig. 1 the invariant mass m_{Bl} is plotted at the LHC; in tables 1 and 2 one can find the average values $\langle m_{Bl} \rangle$ and the statistical errors on the obtained discrepancies for different values of the top mass. We observe a systematic shift of about 800 MeV towards lower values of $\langle m_{Bl} \rangle$ after the inclusion of matrix-element corrections. Also, the results at the Tevatron and at the LHC are the same within the range of 150 MeV. If we parametrise the relation between $\langle m_{Bl} \rangle$ and m_t as a straight line, we find for the LHC, by means of a least square fit:

$$6.1 : \langle m_{Bl} \rangle = 0.568 m_t - 6.004 \text{ GeV}, \quad \epsilon = 0.057 \text{ GeV}; \quad (1)$$

$$6.0 : \langle m_{Bl} \rangle = 0.559 m_t - 3.499 \text{ GeV}, \quad \epsilon = 0.052 \text{ GeV}; \quad (2)$$

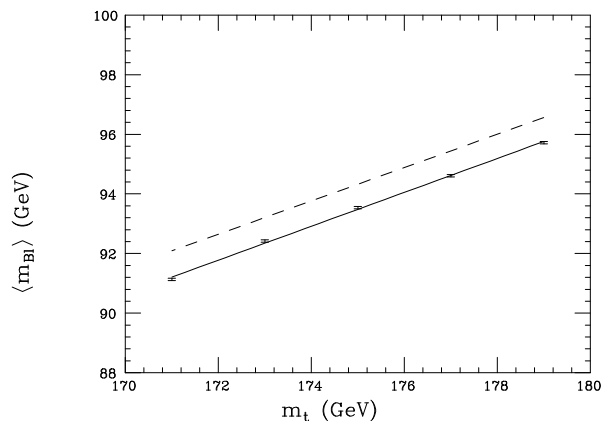
where ϵ is the mean square deviation in the fit. The straight line fits and the HERWIG 6.1 points in table 2 are plotted in Fig. 2: from the values of the slopes, it follows that the discrepancies on $\langle m_{Bl} \rangle$ result in an impact of about $\Delta m_t \approx 1.5$ GeV on the top mass.

In summary, I considered the top mass reconstruction at the LHC using final states with leptons and J/ψ and found that the effect of matrix-element corrections to the HERWIG simulation of top decay is of about 1.5 GeV. More details on this analysis will

m_t	$\langle m_{Bl} \rangle^{6.1}$	$\langle m_{Bl} \rangle^{6.0}$	$\langle m_{Bl} \rangle^{6.0} - \langle m_{Bl} \rangle^{6.1}$
171 GeV	91.18 GeV	92.06 GeV	(0.873 ± 0.037) GeV
173 GeV	92.31 GeV	93.22 GeV	(0.912 ± 0.038) GeV
175 GeV	93.41 GeV	94.38 GeV	(0.972 ± 0.038) GeV
177 GeV	94.65 GeV	95.45 GeV	(0.801 ± 0.039) GeV
179 GeV	95.64 GeV	96.63 GeV	(0.984 ± 0.039) GeV

Table 1. Results at the Tevatron for different values of m_t .

m_t	$\langle m_{Bl} \rangle^{6.1}$	$\langle m_{Bl} \rangle^{6.0}$	$\langle m_{Bl} \rangle^{6.0} - \langle m_{Bl} \rangle^{6.1}$
171 GeV	91.13 GeV	92.02 GeV	(0.891 ± 0.038) GeV
173 GeV	92.42 GeV	93.26 GeV	(0.844 ± 0.038) GeV
175 GeV	93.54 GeV	94.38 GeV	(0.843 ± 0.039) GeV
177 GeV	94.61 GeV	95.46 GeV	(0.855 ± 0.039) GeV
179 GeV	95.72 GeV	96.51 GeV	(0.792 ± 0.040) GeV

Table 2. As in table 1, but for the LHC.**Figure 2.** $\langle m_{Bl} \rangle$ as a function of m_t at the LHC after a fit into a straight line, according to HERWIG 6.1 (solid line) and 6.0 (dotted).

be found in [5], where we shall also study jet distributions and the b -quark fragmentation.

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